

ELECTRIC AND MAGNETIC FIELDS (EMF)¹

The Transrapid Maglev technology produces both electric and magnetic fields around the vehicle and guideway. The vehicle has built-in structural shielding to protect the train operators and passengers. There is also potential for exposures of people near the guideway to EMF generated by the technology. Magnetic fields are of much more concern than electric fields since they are pervasive, penetrate biological tissue, and are more difficult to shield. Measured magnetic fields from the Transrapid Maglev technology have complex frequency spectra that are highly variable over time. This paper compares magnetic fields from the Transrapid Maglev technology to other common sources of EMF and current EMF health standards.

Magnetic Fields and EMF Background Levels.

Magnetic fields are commonly quantified as magnetic field strength with units of gauss (G) or milligauss, mG (one-thousandth of a gauss). Hertz is the unit for measuring the frequency of fields in the number of wave cycles each second. The lower the frequency of a field, the lower its energy. Power frequency fields are low frequency fields and have low energy levels. Microwave and x-ray fields are high frequency fields and have high energy levels.

EMF Magnetic Field Standards.

The standards used today by the United States for assessing extremely low frequency (ELF) magnetic fields are derived from the two guidelines established by international organizations: the World Health Organization (WHO) and International Radiation Protection Association (IRPA). Currently, there is a massive effort devoted to investigate the effects of magnetic fields on human health. In the meantime, these standards (shown in Table 1) have been established to serve as a guideline for comparison in industries or other related fields of study.

Table 1 Summary of Major EMF Standards		
ORGANIZATION	STATIC FIELD	TIME-VARYING FIELD
World Health Organization	20,000 G	10 G
IRPA (50/60 Hz)	1 G (24 hrs/day); 10 G (few hours/day)	Based on ratio between power frequency to magnetic field frequency
ACGIH (60 Hz)	100 G	N/A
Sources: WHO, IRPA. Note: G = Gauss		

The WHO has not set a limit for static or time-varying magnetic fields. Instead, it has provided some guidelines based on scientific studies. According to WHO Health criteria, a static field of less than 20,000 G or time varying field of approximately 10 G is known to have no adverse health effects in humans.

¹ Source: California-Nevada Super Speed Train Project, *Environmental Assessment Las Vegas-Primm Segment*, February 29, 2000.

The IRPA has developed a standard to limit the human exposure to EMF in the 50/60 Hz power frequency. A magnetic field limit of 1 G over a 24 hour period was set for the general public, whereas short term exposure is limited to 10 G for a few hours a day. Occupational exposure limits were also established, which are five times higher than the permitted limit for the general public thus having a wider margin for compliance. Magnetic field limit in the field was also established based on induced currents from power lines. The limit for any frequency other than 50/60 Hz in the field determined by ratio of power frequency to magnetic field frequency.

In the United States, the American Conference of Governmental Industrial Hygienists (ACGIH) has set a threshold limit for 60 Hz magnetic field at 100 G. Similarly, the occupational exposure limit was also determined not to exceed 100 G. It should be made clear that the limit set by this organization is not definitive by any government standards but rather it was determined to be used as a guide for comparison.

Comparison of Maglev Magnetic Fields with Other Magnetic Fields.

This paper focuses on the German Maglev technology used in the Transrapid TR-07. The latest TR-08 technology is planned for the California-Nevada Super Speed Train Project. However, test data on this latest model are not yet available. The new model is expected to improve upon the performance of the TR-07.

External magnetic fields only exist near the guideway when the vehicle is passing. This is because the guideway itself is segmented and a segment is energized only as the vehicle passes. For this reason, the exposure beside the guideway is for a short period of time. Operation of the Maglev system will generate both static and time-varying magnetic fields.

Static Fields. The static fields encountered onboard the TR-07 vehicle are generally within the range of static fields encountered daily from the natural geomagnetic field of the earth. Table 2 provides a comparison of the static fields of the TR-07 with typical static fields.

Table 2 Comparison of Static Fields		
Source/Location	Distance	Magnetic Field (mG)
Natural Geomagnetic Field of the Earth	NA	240-620
TR-07 Passenger Compartment	Floor level – Head level	800-535
TR-07 Guideway	Within 1 meter	500
TR-07 Feeder Cables	NA	Not measurable
Refrigerator w/ magnetic door seal	Within 1 meter	around 1000
Source: <i>EMF Technical Memorandum</i>		
Note: mG = milligauss, (one-thousandth of a gauss)		

Time-Varying Fields. The magnetic fields produced by the TR-07 are highly variable over time, especially at the station and along the guideway. Table 3 compares the time-varying fields of the TR-07 with those from some common appliances. It should be noted that the frequency of household appliances is generally 60 Hz while the majority of the fields generated from the TR-07 are below 47.5 Hz. The comparison was done because there is a lack of data for a similar frequency comparison.

Table 3 Comparison of TR-07 Time-Varying Fields to Other Appliances		
Source/Location	Distance (meters)	Magnetic Field (mG)
TR-07 Passenger Compartment (< 47.5 Hz.)	Floor level – Head level	100-200
TR-07 Guideway (< 47.5 Hz.)	3	65-95
	10	20
TR-07 Power Equipment	5	20
TR-07 Feeder Cables	< 1	2
Microwave Oven (60 Hz.)	0.3	40-80
Electric Range (60 Hz.)	0.03	60-2,000
Hair Dryer (60 Hz.)	0.03	60-20,000
Television (60 Hz.)	1	0.1-2
Source: <i>EMF Technical Memorandum</i>		
Note: mG = milligauss, (one-thousandth of a gauss)		

Magnetic Field Intensity. The magnetic fields found in the passenger compartment of the TR-07 fall well within the intensity levels that characterize magnetic fields found near appliances and at the edge of transmission line rights-of-way. Near the guideway when a train passes by, the magnetic field intensity levels close to the guideway are typical of those found at the edge of transmission line rights-of-way and near household appliances. The magnetic field levels remote from the guideway are similar to fields found near distribution line rights-of-way.

Comparison of TR-07 Fields to Existing Standards.

There are only a few existing standards worldwide that could be used to evaluate the fields produced by the TR-07. The evaluation is provided below.

The World Health Organization's (WHO) "Criteria 69." TR-07 magnetic fields onboard the vehicle are at least two orders of magnitude below the level set as the maximum for continuous exposure by the WHO.

International Radiation Protection Agency (IRPA). The maximum magnetic field intensities found on the TR-07 are one order of magnitude below the 1 Gauss continuous public exposure criteria set by IRPA.

American Conference of Governmental Industrial Hygienists (ACGIH). The magnetic fields onboard the TR-07 are three orders of magnitude below the criteria set by this standard.

Comparison of TR-07 Magnetic Fields to Other Transportation System Fields.

Average time-varying extremely low frequency (ELF) magnetic fields in the TR-07 can be compared with average fields measured in other transportation systems in studies done by US DOT, as shown in Table 4.

Table 4 Comparison of ELF Magnetic Fields in Various Transportation Systems	
Transportation System	Field (mG)
TR-07	64
Ferry Boat	<1
Escalators	2
Moving Walkways	4
Electric Cars and Light Trucks	6
Conventional Cars and Light Trucks	6
Jetliner	14
Electric Shuttle Tram	14
Conventional Transit Bus	17
Electric Shuttle Bus	20
Electric Commuter Train	50
Source: USDOT	
Note: mG = milligauss, (one-thousandth of a gauss); ELF = Extremely low frequency magnetic fields	

Summary of Health Effects of EMF Magnetic Fields.

Numerous laboratory and epidemiological studies have been conducted to evaluate the health risk of exposure to 50 and 60 Hz fields. These are the only “power line” frequencies for which studies have been conducted. These studies, however, do not show a clear pattern of health hazards. First, some but not all animal and cell studies have shown biological changes linked with magnetic field exposure, although it is not clear whether these biological changes would be the same in humans. Second, it is not clear which component of magnetic field exposure might be hazardous.

Many epidemiological studies have been conducted to assess the possible adverse health effects in humans through exposure to EMF. However, the results of these studies remain inconclusive due to lack of complete evidence. Most of these studies have found it difficult to directly measure the health effects as related to EMF exposure. Also, studies based on historical data lack sufficient detail and often have not been able to be reconstructed.